

Laser writing with sub-nanosecond burst of femtosecond pulses using strain accumulation

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Femtosecond laser direct writing and micromachining attract considerable interest for a variety of applications ranging from integrated optics and microfluidics to printable flat optics and multi-dimensional optical data storage. A regular train of femtosecond pulses generated by femtosecond oscillator or regenerative amplifier does commonly used in laser material processing. Micromachining with sub-microsecond bursts of femtosecond pulses has been applied for morphology control of structures generated via accumulation and regulation of a heat deposition [1,2]. In addition to heating a pressure wave and rarefaction in the modified zone are important factors determining the laser induced structural changes [3]. However there is a lack of laser processing experiments with a burst exploiting accumulation of the rarefaction.

Here we have proposed and demonstrated a method of efficient micromachining of silica glass and sapphire with the sub-nanosecond bursts of femtosecond pulses with decaying amplitudes in the burst. We show that the burst with the pulse separation interval in the range 50 – 2000 ps activates an additional mechanism of femtosecond modification based on simultaneous action of laser pulse and rarefaction or tensile strain, produced by cumulative action of previous laser pulses in the burst. Moreover temporal form of the burst minimizes electron-hole plasma region due to the first pulse intensity decreasing down to the threshold of multiphoton absorption. At the same time absorption of the subsequent pulses enhances density of energy deposition in comparison with the single pulse writing, that is the clamping effect originated from beam reflection from electron-hole plasma is reduced. As a result the nano-second burst produces the enhanced refractive index change and the birefringent structure in silica glass even with a single laser shot. Absorption of the second and following pulses in the burst is mainly controlled by transient color centers, and maximized for pulse separation interval in the range 200 - 2000 ps, but crucial role in modification enhancement belongs to the transient tensile strain accumulated by pulse repeating action (Fig.1a).

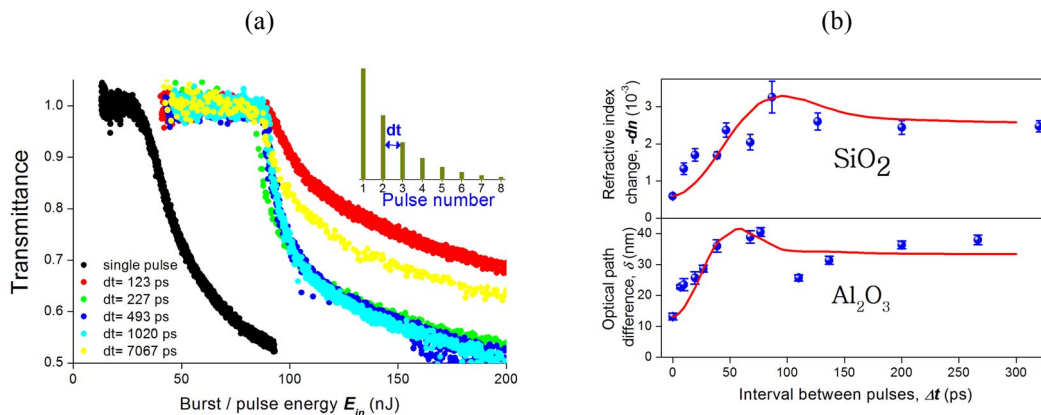


Fig.1 (a) Nonlinear absorption of femtosecond pulse/ burst of femtosecond pulses with different pulse separation intervals as a function of the pulse /burst energy. (b) Measured refractive index change and optical path difference (blue pints) and calculated contribution to permanent refractive index change due to tensile strain in the region of the modification (red line) in dependency of interval between pulses in the burst for silica glass and sapphire.

Largest enhancement of refractive index change was obtained for a burst, which produces highest tensile strain in the exposed region. Optimal pulse separation interval depends on elastic coefficients of the modified material, and it is found to be 95 ps for silica glass and 60 ps sapphire under focusing with NA=0.65 at 1030 nm wavelength (Fig.1b).

The sub-nanosecond burst offers increase of throughput in ultrafast laser micromachining performance.

References

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